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Finarov

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[54] **APPARATUS FOR OPTICAL INSPECTION OF WAFERS DURING POLISHING**

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[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] Appl. No.: **09/047,944**

[22] Filed: **Mar. 25, 1998**

Related U.S. Application Data

[63] Continuation of application No. 08/497,382, Jun. 29, 1995.

[30] **Foreign Application Priority Data**

May 23, 1995 [IL] Israel 113829

[51] **Int. Cl.**^{6} **B24B 49/00**

[52] **U.S. Cl.** **451/6**; 451/41; 451/285; 451/287

[58] **Field of Search** 451/41, 6, 8, 9, 451/63, 285, 287, 288; 156/626, 636.1

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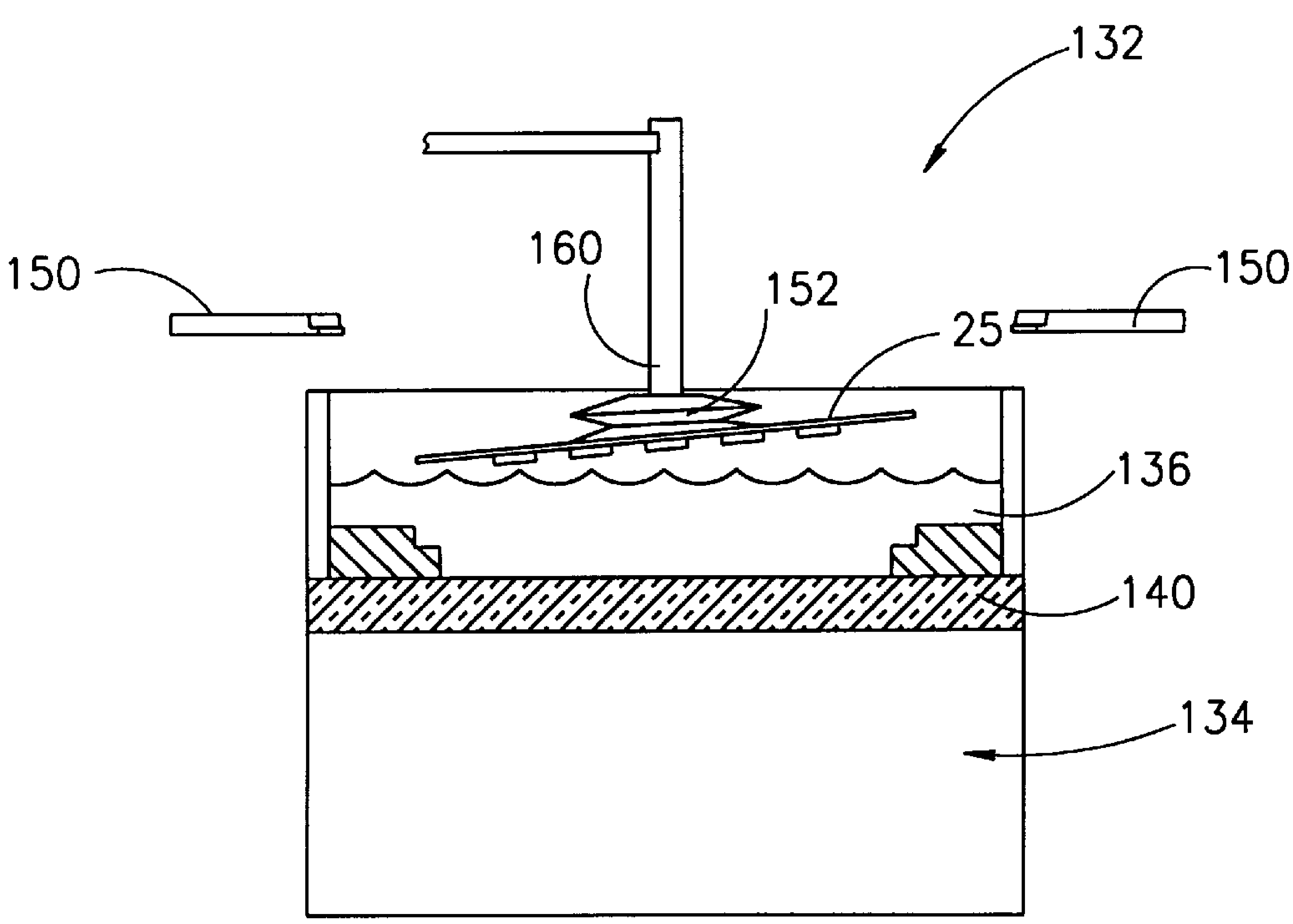
Primary Examiner—Eileen P. Morgan
Attorney, Agent, or Firm—Skjerven, Morrill, MacPherson, Franklin & Friel, LLP

[57] **ABSTRACT**

An optical system is disclosed for the inspection of wafers during polishing which also includes a measurement system for measuring the thickness of the wafer's top layer. The optical system views the wafer through a window and includes a gripping system, which places the wafer in a predetermined viewing location while maintaining the patterned surface completely under water. The optical system also includes a pull-down unit for pulling the measurement system slightly below the horizontal prior to the measurement and returns the measuring system to the horizontal afterwards.

3 Claims, 7 Drawing Sheets



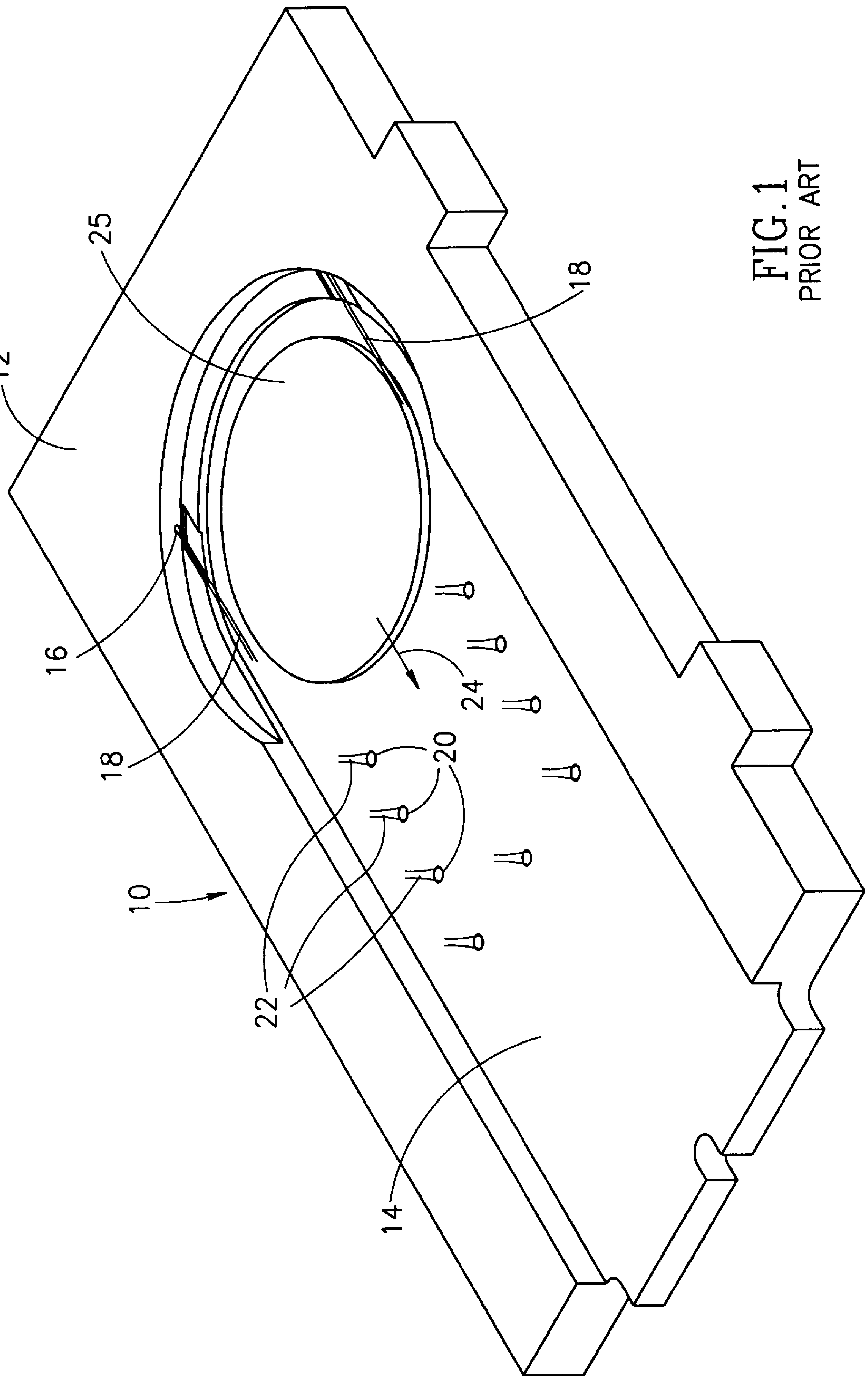
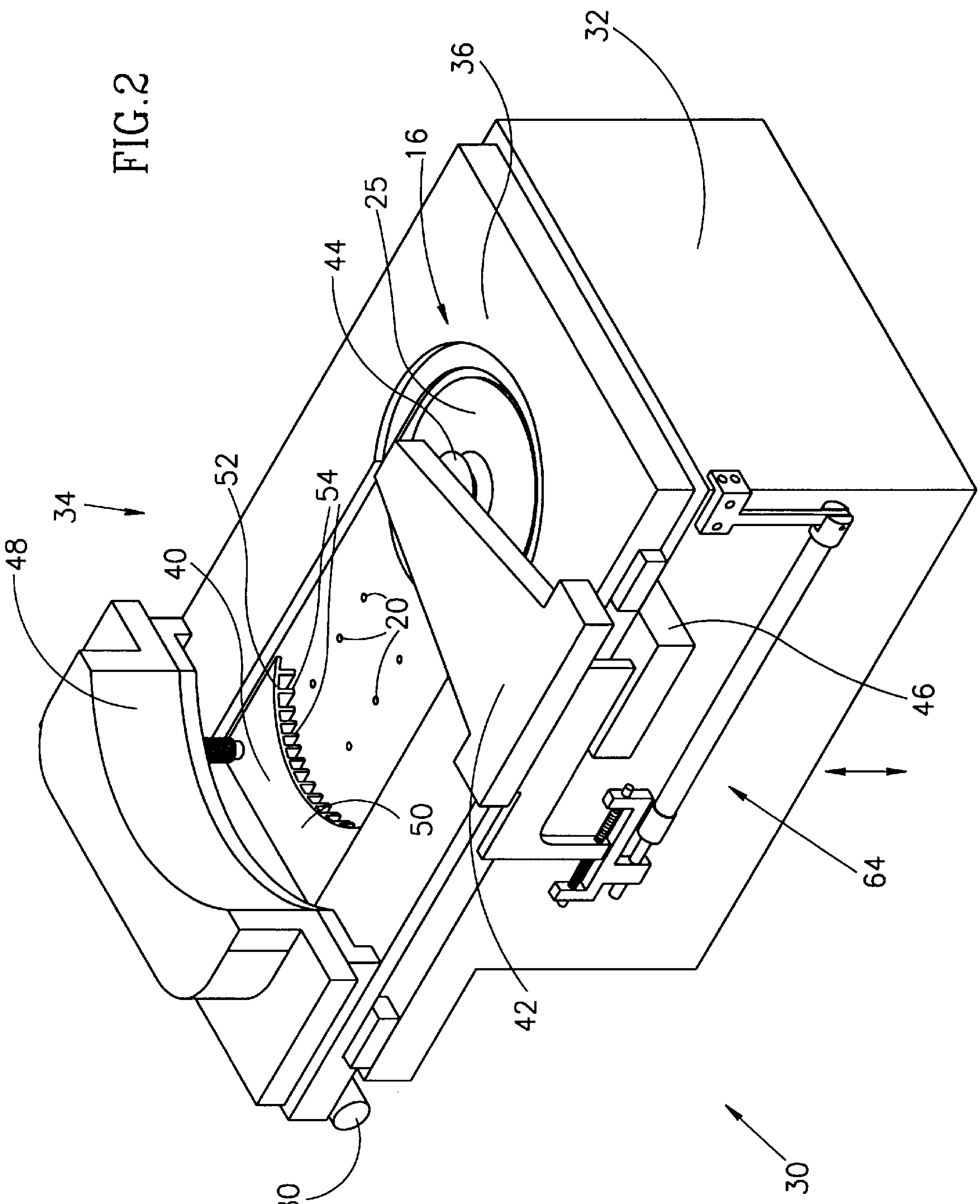


FIG. 1
PRIOR ART

FIG.2



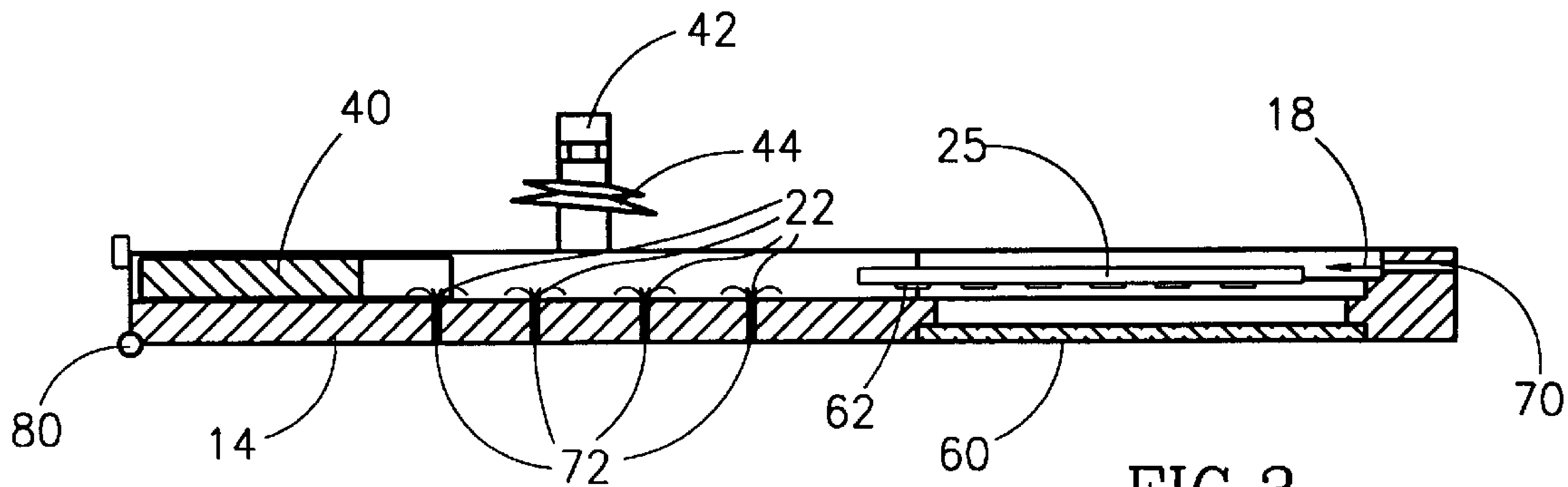


FIG.3

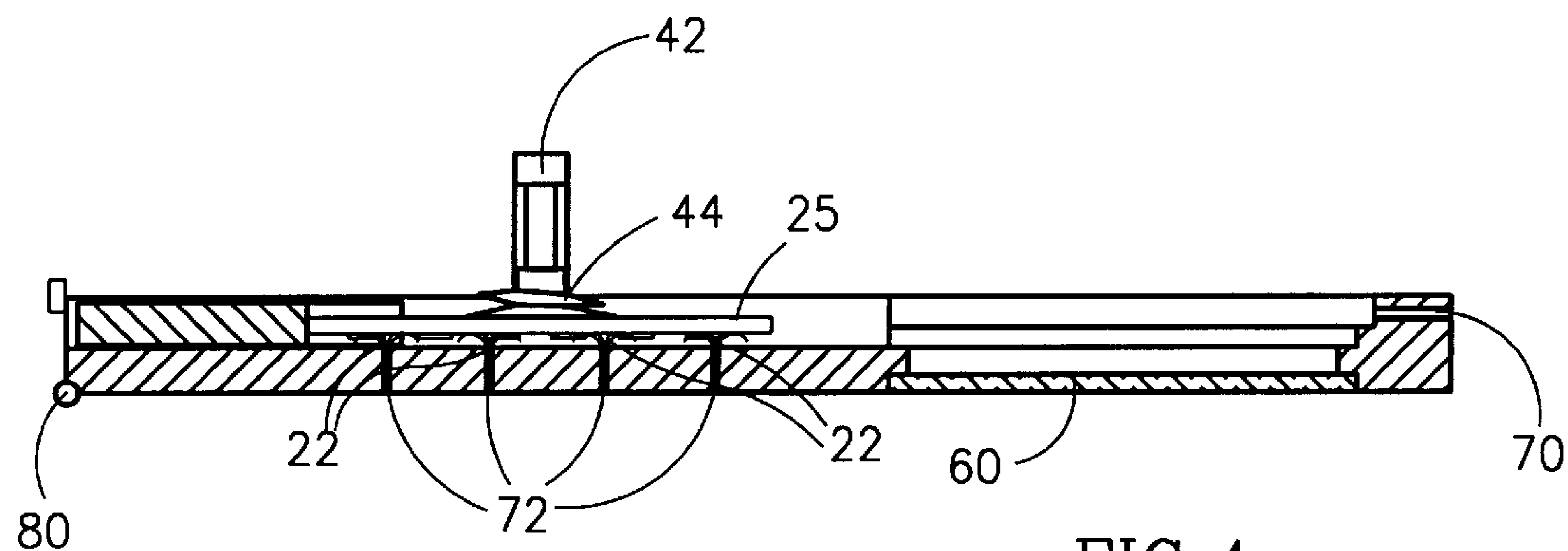


FIG.4

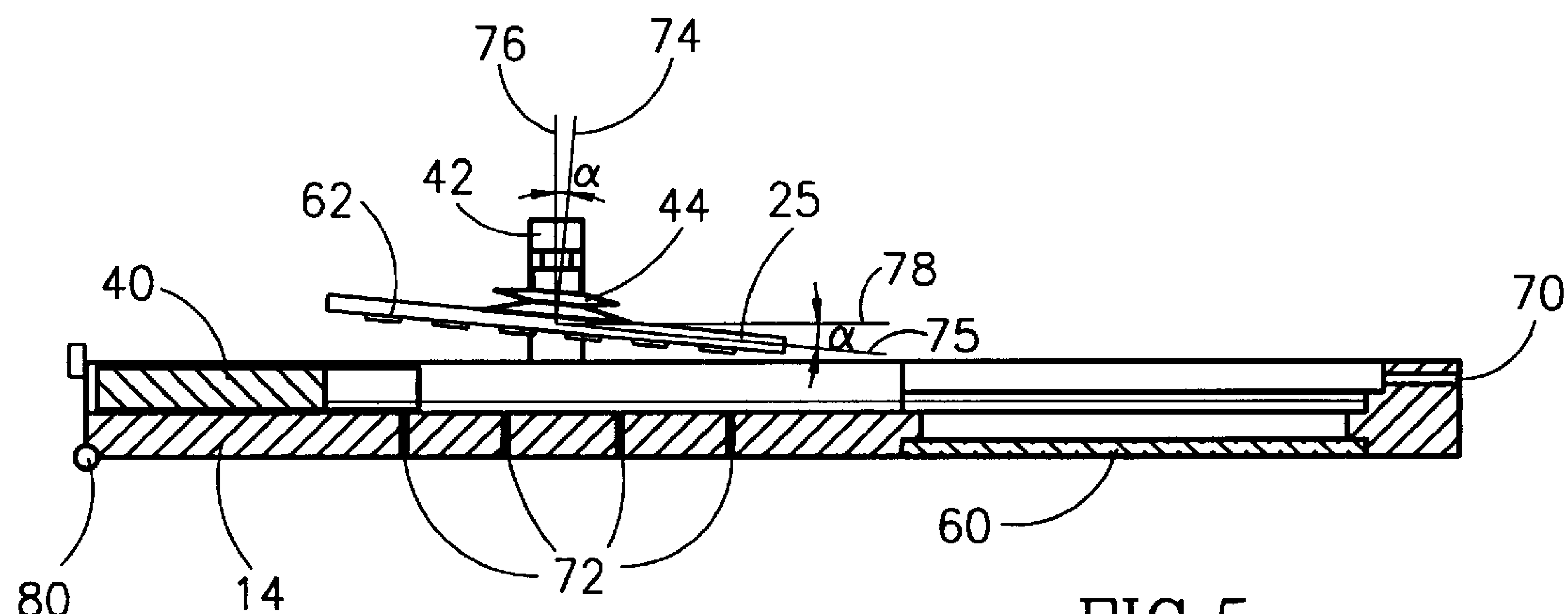


FIG.5

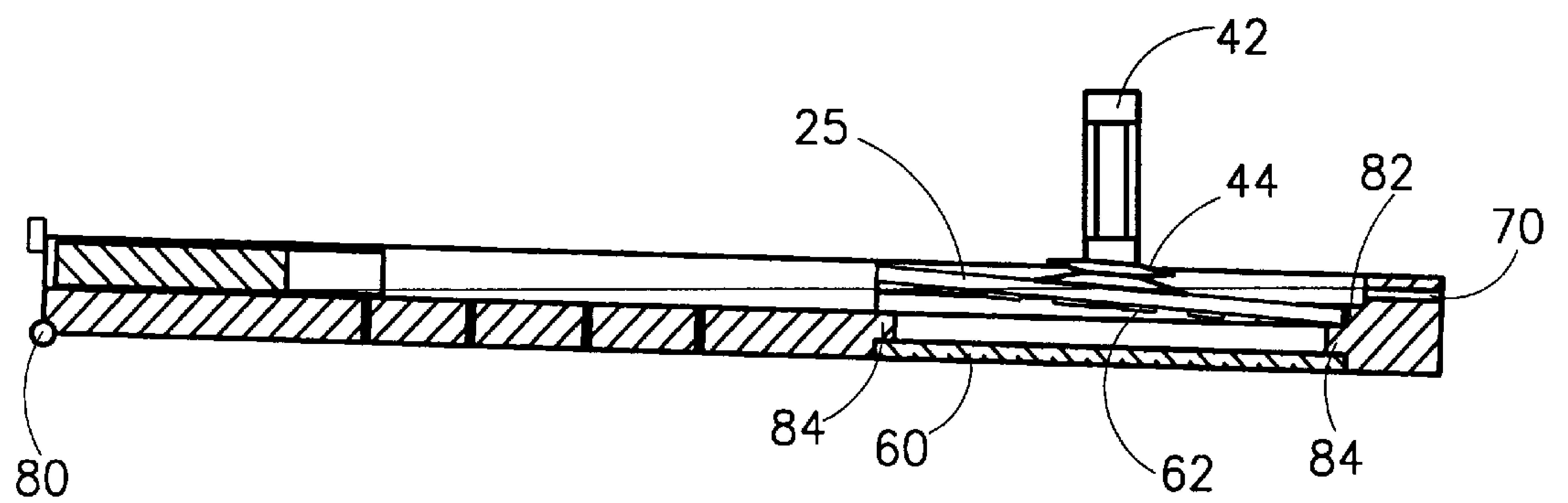


FIG.6

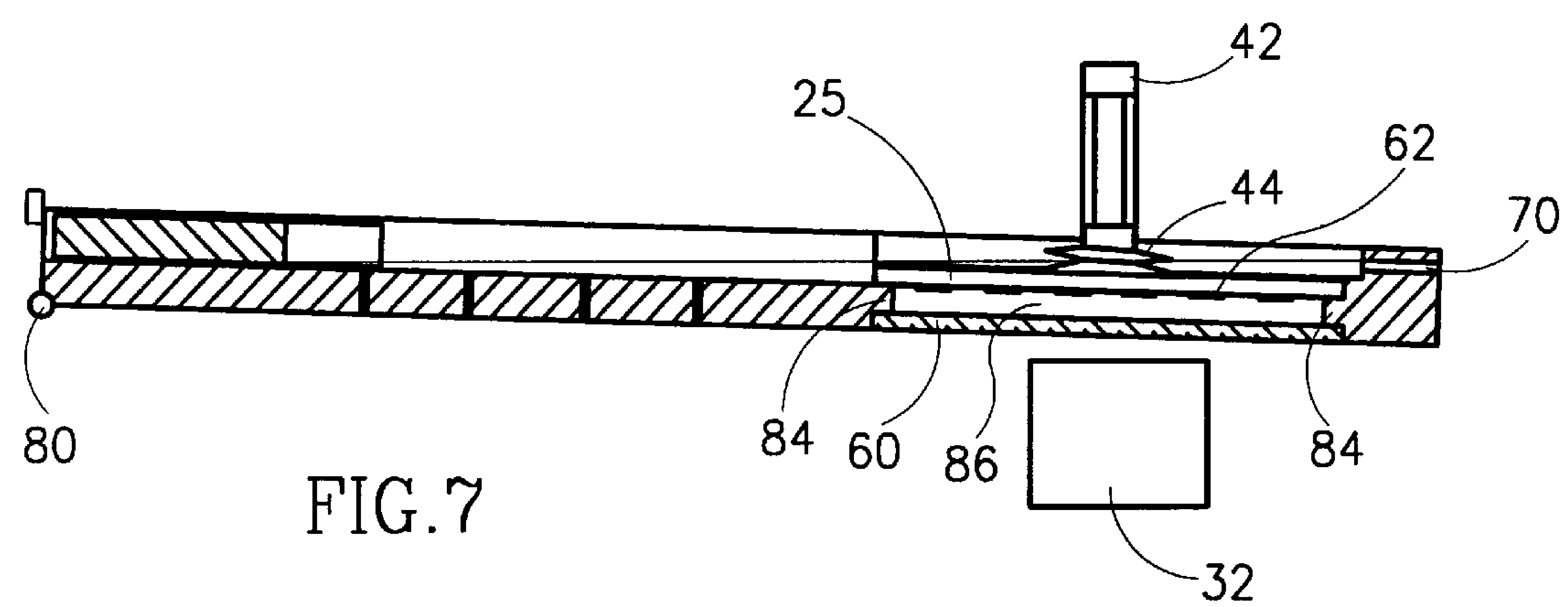


FIG.7

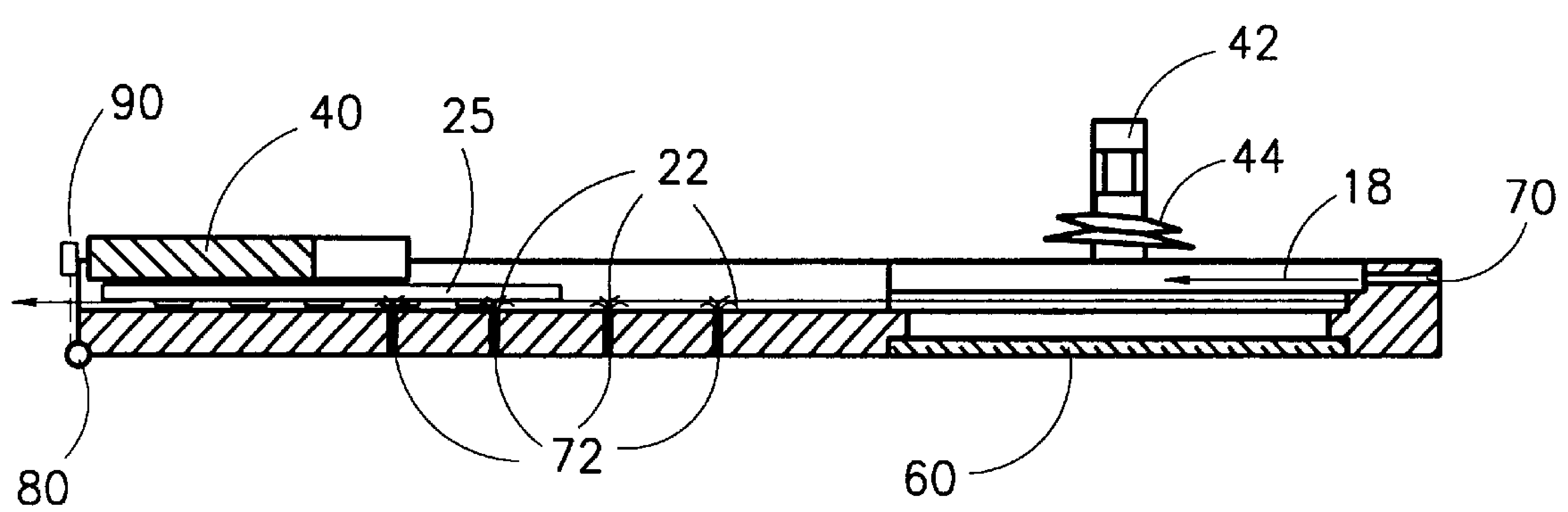


FIG.8

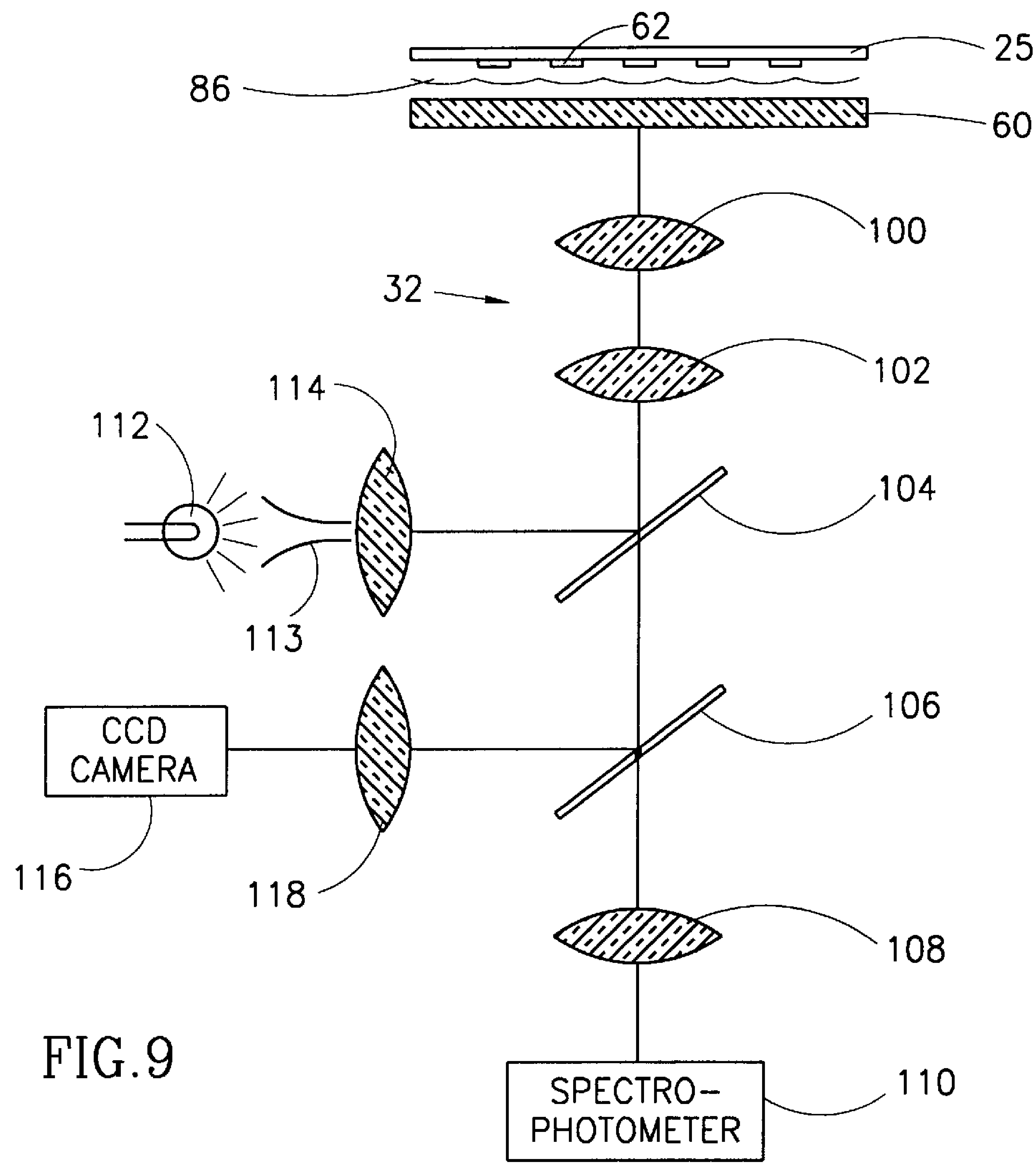

62
25
86
60
100
32
102
114
112
104
113
106
CCD CAMERA
116
118
108
SPECTRO-PHOTOMETER
110

FIG.9

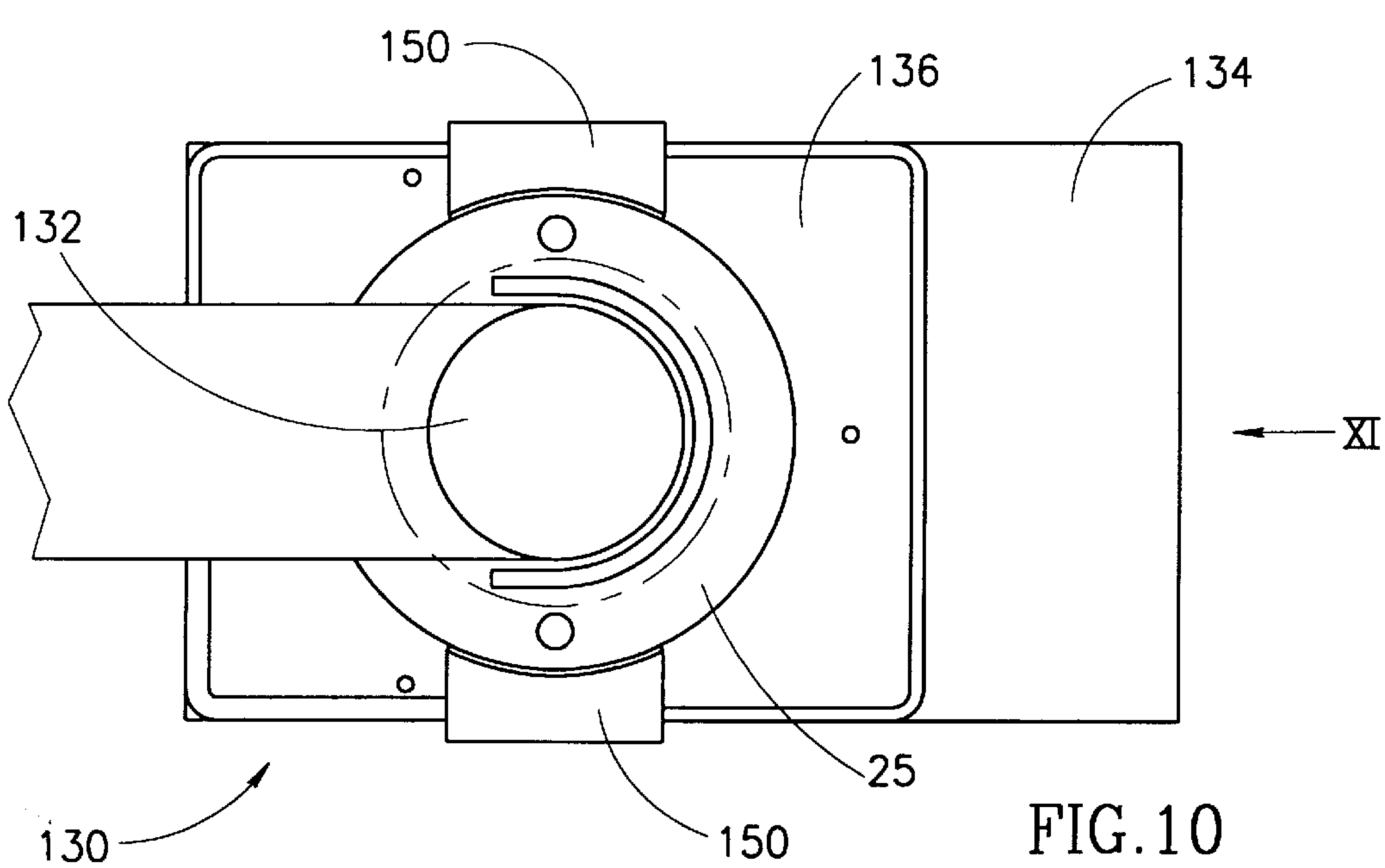

150
136
134
132
XI
25
130
150

FIG.10

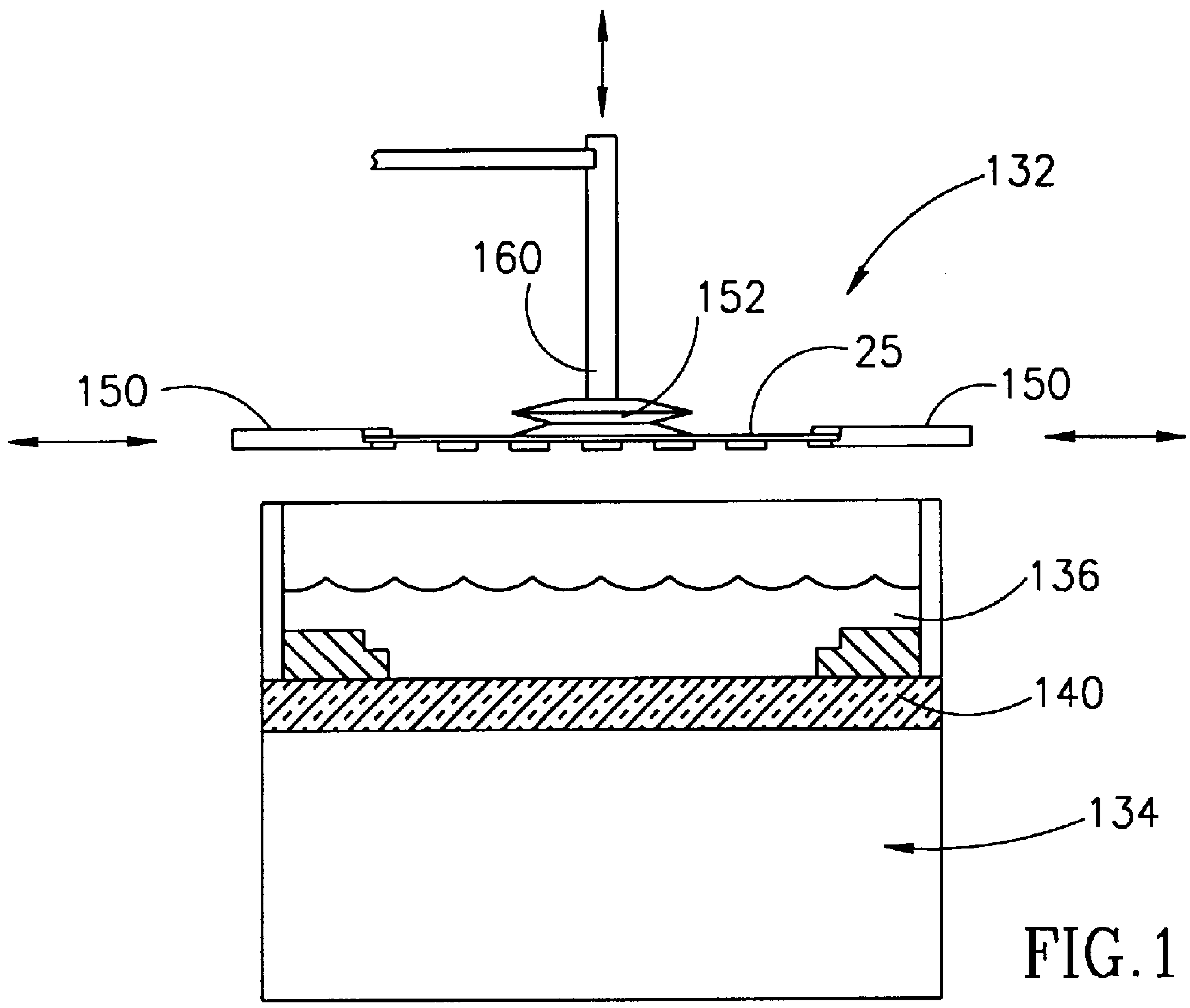

132
160
152
25
150
150
136
140
134

FIG.11

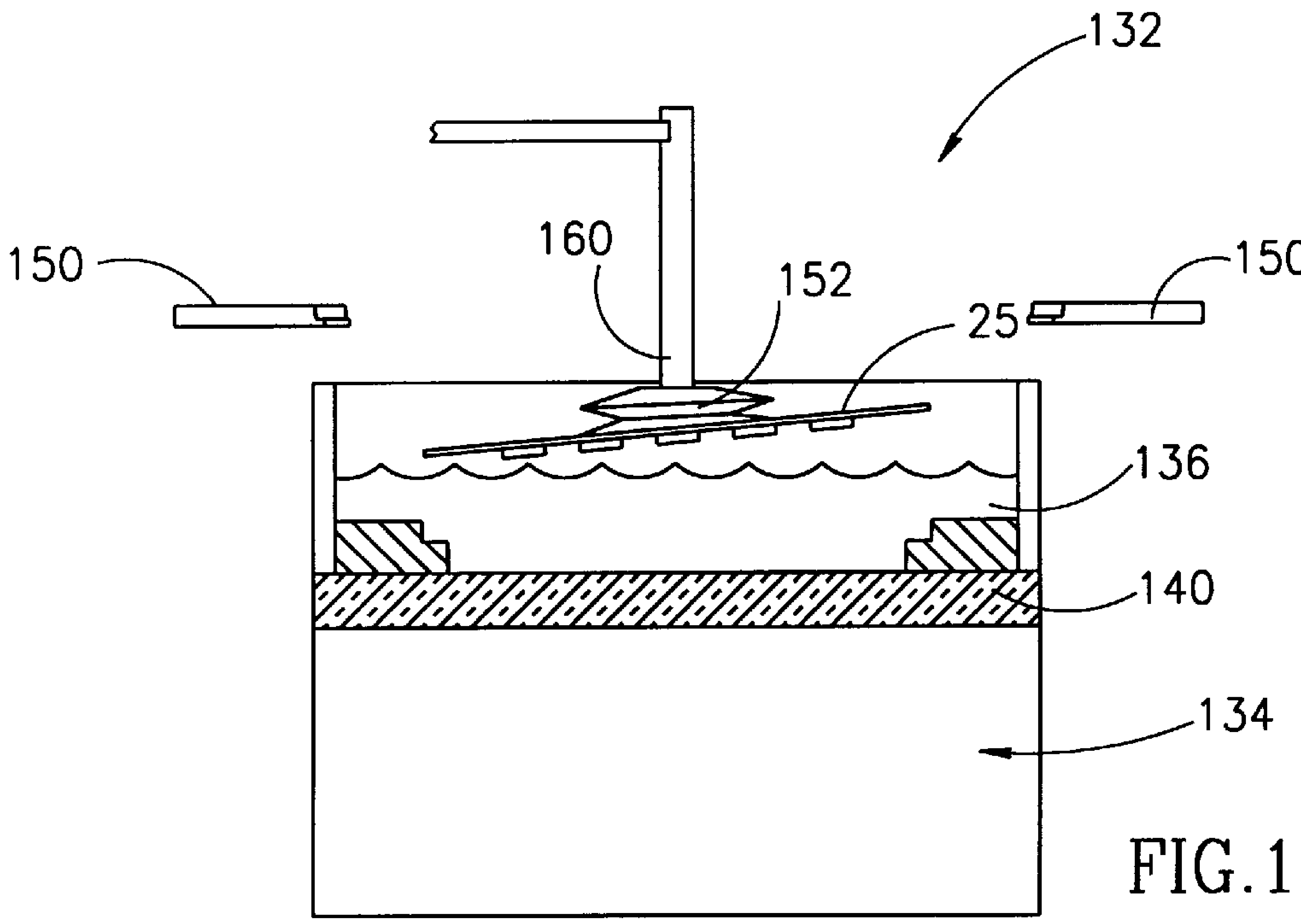

132
150
160
152
25
150
136
140
134

FIG.12

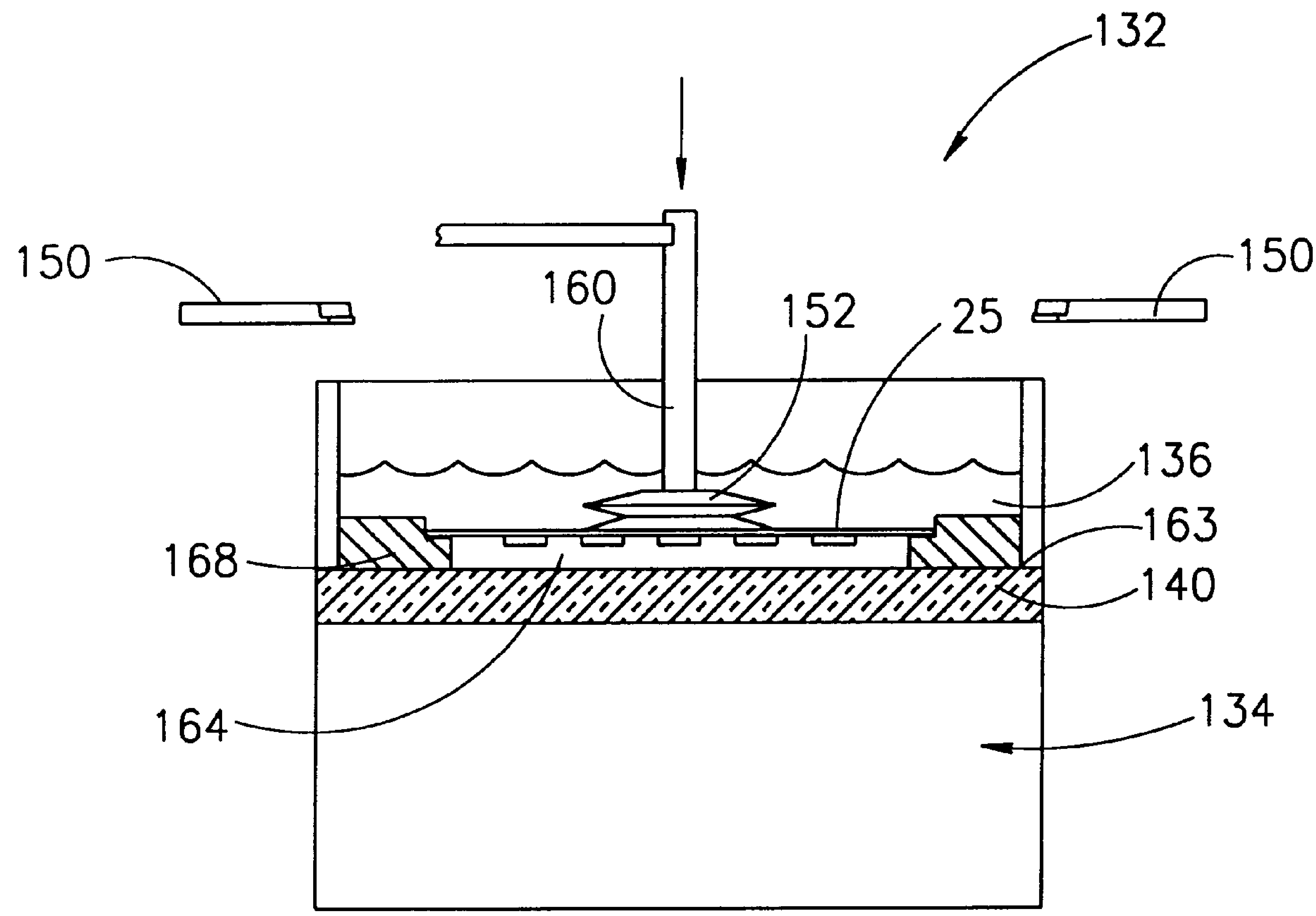


FIG.13

APPARATUS FOR OPTICAL INSPECTION OF WAFERS DURING POLISHING

This Application is a continuation of application Ser. No. 08/497,382, filed Jun. 29, 1995.

FIELD OF THE INVENTION

The present invention relates to wafer polishing apparatus in general and to measuring systems incorporated into such apparatus in particular.

BACKGROUND OF THE INVENTION

Wafer polishing systems are known in the art. They polish the top layer of semi-conductor wafers to a desired thickness. To do so, the wafer being polished is immersed in a slurry of water and chemicals during the polishing process. Once the wafer has been polished and washed down, it is placed into an exit station known by some companies as a "water track", after which the wafer is placed into a cassette of wafers. The cassette is maintained within a water bath until full, after which the entire cassette is brought to a cleaning station to remove any chemicals and slurry particles still remaining on the wafers in the cassette and to dry the wafers. After cleaning, the wafers are brought to a measurement station to determine if the polisher produced the desired thickness of their top layers.

FIG. **1**, to which reference is now briefly made, illustrates a prior art water track, such as the water track of the #372 Polisher manufactured by IPEC Westech Inc. of Phoenix, Ari., USA. The water track, labeled **10**, comprises a frame **12** and a base **14**. Frame **12** has jet holes **16** connected to jets (not shown) which emit streams **18** of water through holes **16**. Base **14** has holes **20** connected to bubblers (not shown) which bubble small amounts of water **22** through holes **20**. When a wafer **25** is dropped into water track **10**, pattern-side down, the jets and bubblers are activated. Streams **18**, from the water jets, serve to force the wafer **25** in the direction indicated by arrow **24**. Small streams **22** push the wafer **25** slightly away from the base **14** and ensure that, while the wafer **25** moves through the track, it never rubs against base **14** and thus, the pattern on the wafer is not scratched.

Other companies produce polishers whose exit stations are formed just of the cassettes. Such a polisher is produced found in the 6DS-SP polisher of R. Howard Strasbaugh Inc. San Luis Obispo, Calif., USA.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide a measurement system installable within a polishing machine and, more specifically, within the exit station of a polishing machine.

In accordance with a preferred embodiment of the present invention, the present invention includes an optical system, which views the wafer through a window in the exit station, and a gripping system, which places the wafer in a predetermined viewing location within the exit station while maintaining the patterned surface completely under water. The present invention also includes a pull-down unit for pulling the measurement system slightly below the horizontal prior to the measurement and returns the measuring system to horizontal afterwards.

In accordance with a first preferred embodiment of the present invention, the gripping system includes a raisable gate which collects the wafer in a predetermined location, and a gripper which grips the wafer, carries it to the viewing location and immerses the wafer, along a small angle to the horizontal, in the water or water. The gripper also holds the wafer in place during the measurement operation, after which, it releases the wafer and the raisable gate is raised.

The present invention incorporates the method of immersing an object into water such that very few bubbles are produced on the wafer surface. The method of the present invention preferably includes the step of immersing the object while it is held such that its surface plane is at a small angle to the horizontal.

In a second embodiment, the measurement system includes a water bath and a gripping system thereabove. The gripping system includes wafer holding elements, which receive the wafer, and a gripper whose initial location is above the expected reception location of the wafer. The gripper is flexibly connected at an angle to a piston such that the wafer is immersed in the water at an angle to the horizontal.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

FIG. **1** is a schematic illustration of a prior art water track;

FIG. **2** is a schematic illustration of a measurement system installable within a polishing machine, the measurement system being constructed and operative in accordance with a preferred embodiment of the present invention;

FIGS. **3**, **4**, **5**, **6**, **7** and **8** are schematic, side view illustrations of a gripping system forming part of the measurement system of FIG. **2** in various stages of operation;

FIG. **9** is a schematic illustration of an example optical system forming part of the measurement system of the present invention;

FIG. **10** is a top view of a second embodiment of the measurement system of the present invention; and

FIGS. **11**, **12** and **13** are side views of the measurement system during receipt, transfer and measurement of the wafer, respectively.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Reference is now made to FIG. **2**, which illustrates a measurement unit installable within a polishing machine, such as the IPEC Westech machine, the measurement system being constructed and operative in accordance with a preferred embodiment of the present invention and to FIGS. **3**, **4**, **5**, **6**, **7** and **8** which illustrate the operation of a gripping system forming part of the measurement system of FIG. **2**. Similar reference numerals are utilized to refer to elements of the water track previously discussed.

The measurement system, labeled **30**, comprises an optical system **32** and a gripping system **34** operative in conjunction with a water track **36**. The optical system **32** can be any optical system which measures the thickness of the top layer of the wafer through water. FIG. **9** provides one example of such a optical system; other optical systems are also incorporated into the present invention.

The gripping system **34** comprises a raisable gate **40**, a translatable gripper **42**, a vacuum pad **44** and a vacuum system **46**. Gate **40** is controlled by a lifting mechanism **48** which raises and lowers gate **40** as necessary. Gate **40** has an upper surface **50** with a curved outer edge **52** and a plurality of protrusions **54** extending downward into the water from the upper surface **50**. Protrusions **54** provide a lower surface onto which the gate **40** is lowered while enabling the water to pass through the gate **40**. Curved edge **52** is shaped to match the curved edge of the wafer **25** so that, when gate **40** is in its lowered position, gate **40** will both keep the wafer **25** from passing out of the water track and to hold the wafer **25** in a repeatable location.

Gripper **42** translates between the wafer collecting position defined by the curved edge **52** and a wafer measuring location indicated in FIG. **2** by the wafer **25**. Although not visible in FIG. **2**, the base of the water track at the wafer measuring location has been replaced by a window **60** (FIGS. **3–9**) to enable the optical system **32** to view the patterned surface **62** of the wafer **25**. For the purposes of the explanation, the patterned surface **62** is shown exaggeratedly in the Figures.

Gripper **42** can be translated by any translation system; an example of one such system is provided in FIG. **2** and labeled **64**.

The vacuum pad **44** is typically a bellows-shaped pad and is mounted at the end of the gripper **42** and is connected to the vacuum system **46**. The vacuum pad **44** creates a suction so that gripper **49** can raise the wafer **25** and move it from the wafer collecting position to the waler measuring location. In addition, the vacuum is maintained during the measurement and only released once the measurement is complete.

FIGS. **3–8** illustrate the operation of the gripping system **34**. Initially, and as shown in FIG. **3**. the jets, labeled **70**, and the bubblers, labeled **72**, of the water track are operated and the gate **40** is lowered. The polisher (not shown) places the wafer **25** within the water track and the streams **16** from the jets **70** push the wafer **25** towards the gate **40**. The gripper **42** is at the wafer collecting position, shown to the left in FIGS. **3–8**.

Once the wafer **25** is in the wafer collecting position, as shown in FIG. **4**, gripper **42** lowers vacuum pad **44** to grab the wafer **25**. It will be appreciated that gripper **42** can be formed of any suitable mechanism, such as a piston, which can move vacuum pad **44** up and down on command. Since bubblers **72** are operating, the small streams **22** maintain the wafer **25** away from the base **14** of the water track.

The gripper **42** then pulls the wafer **25** out of the water (FIG. **5**) and the jets **70** are deactivated. In accordance with a preferred embodiment of the present invention, the axis **74** of symmetry of the vacuum pad **44** is formed at a small angle α from the vertical axis **76**. As a result, a long axis **75** of the wafer **25** is at the same small angle α to the horizontal axis **78**. Angle α is typically in the range of 2–5°.

Translation unit **64** then moves gripper **42** to the wafer measuring position, shown to the right in FIGS. **4–8**. At the same time and as shown in FIG. **6**, a pull-down mechanism slightly lowers the entire water track, gripping and optical system unit (at an angle of 1–3°), about a hinge **80** (FIGS. **2–8**), to force the water toward the wafer measuring position. Other methods of forcing the water towards the measuring position are also incorporated in the present invention.

After the lowering of the water track, gripper **42** lowers the wafer **25** towards the window **60**. Since the vacuum pad **44** is angled, the wafer **25** does not enter the water all at once. Instead, wafer **25** enters the water gradually. Initially, only the side labeled **82** is immersed. As the gripper **42** pushes the vacuum pad **44** further down, more and more of the wafer **25** becomes immersed until the entire wafer **25** is within the water. Vacuum pad **44** is flexible enough to accommodate the changed angle of wafer **25**.

It will be appreciated that, by gradually immersing the wafer in the water, few, if any, bubbles are created near the patterned surface of the wafer **25**.

It is noted that the wafer **25** does not rest against the window **60**. Instead, it is held against protruding surfaces **84** such that there is a layer of water **86** between the wafer **25** and window **60**. Due to the gradual immersion of wafer **25**, layer **86** of water has little, if any, bubbles in it and therefore provides a uniform connecting medium between the optical system **32** and the patterned surface **62** of wafer **25**.

Once the optical system **32** has finished measuring the patterned surface **62** of wafer **25**, gripper **42** returns vacuum pad **44**, with wafer **25** still attached, to its upper position. The pull-down mechanism rotates the water track about hinge **80** to return to its original position, gate **40** is raised, and jets **70** and bubblers **72** are activated. The vacuum system **46** releases the vacuum and the wafers **25** falls into the water track. The flow of water causes the wafer **25** to move toward and under the now raised gate **40**. A sensor **90** determines when the wafer **25** successfully passes out of the water track. The process described hereinabove can now begin for the next wafer.

Reference is now made to FIG. **9** which schematically illustrates an example of a suitable optical system **32**. Optical system **32** is a microscope-based spectrophotometer and comprises an objective lens **100**, a focusing lens **102**, a beam splitter **104**, a pin hole mirror **106**, a relay lens **108** and a spectrophotometer **110**. It additionally comprises a light source **112**, a condenser **114**, a charge coupled device (CCD) camera **116** and a second relay lens **118**.

Light from light source **112** is provided, along an optical fiber **113**, to condenser **114**. In turn, condenser **114** directs the light towards beam splitter **104**. Beam splitter **104** directs the light towards the wafer surface via lenses **102** and **100** and via window **60** and water layer **86**.

The reflected light from the patterned surface **62** is collected by objective **100** and focused, by lens **102**, onto pin hole mirror **106**. Relay lens **108** receives the light passed through pin hole mirror **106** and focusses it onto the spectrophotometer **110**.

Pin hole mirror **106** passes light through its hole towards spectrophotometer **110** and directs the light hitting the mirror surface towards CCD camera **114**. Second relay lens **118** receives the light reflected by pin hole mirror **106** and focusses it onto the CCD camera **114**.

Since the pinhole is placed at the center of the image plane which is the focal plane of lens **102**, it acts as an aperture stop, allowing only the collimated portion of the light beam to pass through. Thus, the pinhole drastically reduces any scattered light in the system. Relay lens **108** collects the light from the pinhole and provides it to spectrophotometer **110**.

Furthermore, since the pinhole is located at the image plane of the optical imaging system (lenses **100** and **102**), only that portion of the light, reflected from the surface of wafer **25**, which is the size of the pinhole divided by the magnification will come through the pinhole. Relay lens **118** collects the light and focusses it onto the CCD camera **114**.

The pinhole serves to locate the measurement spot in the image of the wafer **25**. Since the pinhole allows light to pass through it, rather than being reflected toward the CCD camera **114**, the pinhole appears as a sharp dark point in the image produced by the lens **118**. Thus, when viewing the CCD image, the location of the measurement spot is immediately known, it being the location of the dark spot.

Reference is now made to FIGS. **10–13** which illustrate the thickness measuring of the present invention implemented in a polishing machine similar to that produced by Strasbaugh which has no water track. In this embodiment, the polishing machine or an external robot (not shown) brings the wafers **25** to an exit station of the polisher. When the measurement has finished, the robot brings the wafers **25** to their cassette at another exit station. FIG. **10** is a top view and FIGS. **11**, **12** and **13** illustrate the measuring station in three states.

The measuring station **130** comprises a gripping unit **132**, an optical system **134** and a water bath **136**. The optical system **134** is located beneath the water bath **136** and can be any suitable optical system, such as the one described hereinabove. As in the previous embodiment, the water bath **136** has a window in its bottom surface, labeled **140** in FIG. **11**, through which the optical system **134** can illuminate the wafer **25**.

The gripping unit **132** comprises a wafer support **150**, illustrated as being formed of two support elements, a vacuum pad **152**, similar to vacuum pad **44**, and a piston **160**. The polisher places the wafer **25** on the wafer support **150** while the vacuum pad **152** is initially in a position above the support **150**, as shown in FIG. **11**. Once the wafer support **150** has the wafer in a predefined position, the vacuum pad **152**, which is controlled by piston **160**, moves toward the wafer and grabs it by applying a vacuum. Now that the vacuum pad **152** is holding the wafer, the wafer supports **150** move away, as indicated.

The piston **160** then pushes the vacuum pad-wafer combination toward the water bath **136**. This is shown in FIG. **12** which also illustrates that the vacuum pad **152** holds the wafer **25** at a small angle α to the horizontal. The angle α is provided since, as in the previous embodiment, the axis of symmetry of the vacuum pad **152** is formed at a small angle α from the vertical axis. As in the previous embodiment, by immersing the wafer **25** into the water at the angle α, few, if any, bubbles, remain on the undersurface of the wafer after full immersion.

FIG. **13** illustrates the wafer **25** at its fully immersed, measurement position. Typically, wafer **25** does not directly touch the water surface **163** of the window **140**; instead, it sits on a measurement support **168**. The result is that there is a water layer **164** between the wafer **25** and the surface **163** of the window.

Once the measurement process has finished, the piston **160** returns the wafer **25** to its original position and the wafer support elements **150** return to their wafer receiving position. The piston **160** places the wafer **25** on the wafer support elements **150** and releases the vacuum. The external robot can now take the wafer to another exit station where there is a cassette of processed and measured wafers.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined by the claims which follow:

What is claim is:

1. A wafer polishing apparatus comprising:

a polishing unit for polishing a top layer of a wafer in the presence of a liquid;

an optical measurement station in communication with said polishing unit; and

means for moving said wafer from said polishing unit to said optical measurement station, while said wafer is still wet;

said optical measurement station comprising;

a liquid holding unit for receiving said wafer, said liquid holding unit having a bottom surface, and at least a portion of said bottom surface formed by a window, through which at least a portion of said top layer of said wafer is viewable; and

an optical thickness measuring unit in operative communication with said liquid holding unit, said optical thickness measuring unit for measuring the thickness of said top layer of said wafer through said window while said wafer is in said liquid holding unit.

2. The apparatus according to claim **1** and having a layer of liquid between said window and said wafer during operation of said optical thickness measuring unit.

3. The apparatus according to claim **1**, wherein said optical thickness measuring unit comprises:

an illumination optical unit for directing light towards said wafer;

an imaging unit for imaging at least said top layer of said wafer;

a spectrophotometric detector; and

an optical assembly in operative communication with said imaging unit and said spectrophotometric detector for providing light reflected from said wafer separately to said imaging unit and to said spectrophotometric detector, said optical assembly comprising, an objective lens, a pinhole mirror and first and second relay lenses, wherein said first relay lens focuses the light passing through said pinhole mirror onto said spectrophotometric detector and wherein said second relay lens focuses the light reflected from said pinhole mirror onto said imaging unit.

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